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... the measured small changes in **magnetic** field in another, distant **borehole**;
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Combined 3-D Interpretation of Airborne, Surface, and Borehole Vector Magnetics at the McConnell Nickel Deposit

Edna L. Mueller,[a] William A. Morris,[a] Patrick G. Killeen,[b] and Steven Balch[c]
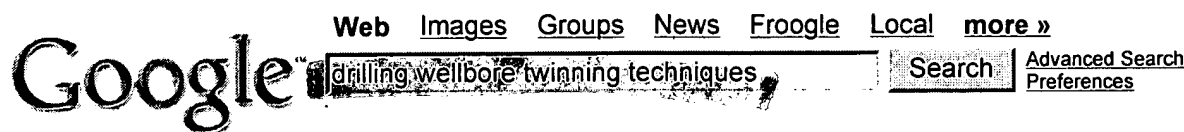
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[b]*Borehole Geophysics Section, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada, K1A 0E8*

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ABSTRACT

The McConnell nickel deposit is an elliptical amphibolite-biotite quartz diorite pod within the Sudbury Metabreccia that surrounds the main mass of the Sudbury Igneous Complex. The geometry of the deposit is tabular with a strike length of approximately 152 m and depth extent of 610 m. Various magnetic surveys were conducted in this study area. A regional aeromagnetic survey was conducted by the Ontario Geological Survey. A more detailed ground magnetics survey and a borehole magnetic survey are used in the interpretation of the character of the causative body. Five boreholes which intersect the deposit at 40 m, 105 m, 135 m, 210 m, and 250 m provide good lithological control of the deposit with depth. Eight other boreholes used in this study did not have logged lithology, but all 13 holes were logged with gamma ray, density, spectral gamma-gamma, IP, resistivity, SP, magnetic susceptibility, temperature, and 3-component magnetic field probes. Only the measurements of magnetic susceptibility and 3-component magnetic field measurements and their interpretation will be discussed in this paper. 3-component magnetic vector surveys show different signatures for boreholes that pass through a magnetic source body (an *onhole* source), and for holes that are adjacent to the source body (an *offhole* source). Using inverse models of the surface magnetic data, values of magnetic susceptibility and magnetic remanence direction and intensity for the various lithological units are estimated. Modelling of the subsurface data reveals fine structure within the ore body and may be used to estimate the direction and distance to other *offhole* magnetic bodies.

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S2	7	wellbore and drill$3 and passive same rang$3 same technique$3 and survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:38
S3	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:49
S4	40	("20020005286" | "20020005297" | "20020116130" | "20020133958" | "20020144417" | "3170137" | "3725777" | "4302886" | "4909336" | "4987684" | "5155916" | "5194859" | "5220963" | "5259466" | "5351755" | "5415238" | "5419405" | "5439064" | "5512830" | "5657826" | "5675488" | "5842149" | "5960370" | "5996711" | "6003599" | "6021377" | "6065550" | "6092610" | "6145378" | "6173773" | "6192748" | "6233524" | "6267185" | "6296066" | "6315062" | "6321456" | "6453239" | "6470976" | "6480119").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2005/06/01 17:41
S5	21	("4231252" | "4472884" | "4510696" | "4559713" | "4709486" | "4906388" | "4909336" | "4987684" | "5410303" | "5435069" | "5623407" | "5657547" | "5657826" | "5739431" | "5787997" | "5821414" | "5970787" | "6109370" | "6179067" | "6347282" | "RE33708").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2005/06/01 17:49
S6	22	("4231252" | "4472884" | "4510696" | "4559713" | "4709486" | "4906388" | "4909336" | "4987684" | "5410303" | "5435069" | "5623407" | "5657547" | "5657826" | "5739431" | "5787997" | "5821414" | "5970787" | "6109370" | "6179067" | "6347282" | "RE33708").PN.	USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:49
S7	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:38

S8	0	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	USOCR	OR	ON	2005/06/01 17:50
S9	0	wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USOCR	OR	ON	2005/06/01 17:50
S10	38	wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USPAT	OR	ON	2005/06/01 17:50
S11	0	33/304.ccls. and wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USPAT	OR	ON	2005/06/01 17:51
S12	201	33/304.ccls.	USPAT	OR	ON	2005/06/01 17:51
S13	0	33/304.ccls. and twinning	USPAT	OR	ON	2005/06/01 17:51
S14	1	33/304.ccls. and twin$3	USPAT	OR	ON	2005/06/03 15:11
S15	1	33/304.ccls. and twin$3	USPAT	OR	ON	2005/06/02 15:52
S16	201	33/304.ccls.	USPAT	OR	ON	2005/06/02 15:53
S17	33	33/304.ccls. and wellbore	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:16
S18	2	33/304.ccls. and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:18
S19	0	174/45.ccls. and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:18
S20	7	(174/45.ccls. or 33/304.ccls. or 324/345.ccls. or 166/250.13.ccls. or 702/10.ccls. or 166/255.ccls.) and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:22
S21	6	((borehole) or (bore same hole)) same twin$4 and vector and magnetic	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:29

S22	61	horizon$4 same plane and vertical and magnetic same north and magnetic same azimuth and magnetic same east	US-PGPUB; USPAT	OR	ON	2005/06/02 16:31
S23	28	horizon$4 same plane and vertical and magnetic same north and magnetic same azimuth and magnetic same east and borehole	US-PGPUB; USPAT	OR	ON	2005/06/02 16:31
S24	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:45
S25	36	("3725777" "5512830" "5657826" "3170137" "4302886" "4909336" "4987684" "5194859" "5220963" "5259466" "5351755" "5415238" "5419405" "5439064" "5842149" "5996711" "6003599" "6021377" "6065550" "6092610" "6145378" "6173773" "6192748" "6233524" "6267185" "6296066" "6315062" "6453239" "6470976" "200200052286" "20020005297" "20020116130" "20020133958" "5675488" "6321456" "6480119" "20020144417").pn.	US-PGPUB; USPAT	OR	ON	2005/06/02 16:58
S26	50	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn.	US-PGPUB; USPAT	OR	ON	2005/06/03 15:10

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
Si	3	well same twin$4 same borehole same survey$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:36
S2	7	wellbore and drill$3 and passive same rang$3 same technique$3 and survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:38
S3	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:49
S4	40	("20020005286" | "20020005297" | "20020116130" | "20020133958" | "20020144417" | "3170137" | "3725777" | "4302886" | "4909336" | "4987684" | "5155916" | "5194859" | "5220963" | "5259466" | "5351755" | "5415238" | "5419405" | "5439064" | "5512830" | "5657826" | "5675488" | "5842149" | "5960370" | "5996711" | "6003599" | "6021377" | "6065550" | "6092610" | "6145378" | "6173773" | "6192748" | "6233524" | "6267185" | "6296066" | "6315062" | "6321456" | "6453239" | "6470976" | "6480119").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2005/06/01 17:41
S5	21	("4231252" | "4472884" | "4510696" | "4559713" | "4709486" | "4906388" | "4909336" | "4987684" | "5410303" | "5435069" | "5623407" | "5657547" | "5657826" | "5739431" | "5787997" | "5821414" | "5970787" | "6109370" | "6179067" | "6347282" | "RE33708").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2005/06/01 17:49

S6	22	("4231252" | "4472884" | "4510696" | "4559713" | "4709486" | "4906388" | "4909336" | "4987684" | "5410303" | "5435069" | "5623407" | "5657547" | "5657826" | "5739431" | "5787997" | "5821414" | "5970787" | "6109370" | "6179067" | "6347282" | "RE33708").PN.	USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/01 17:49
S7	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:38
S8	0	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	USOCR	OR	ON	2005/06/01 17:50
S9	0	wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USOCR	OR	ON	2005/06/01 17:50
S10	38	wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USPAT	OR	ON	2005/06/01 17:50
S11	0	33/304.ccls. and wellbore and drill$3 and passive and rang$3 and technique$3 and borehole and survey$3	USPAT	OR	ON	2005/06/01 17:51
S12	201	33/304.ccls.	USPAT	OR	ON	2005/06/01 17:51
S13	0	33/304.ccls. and twinning	USPAT	OR	ON	2005/06/01 17:51
S14	1	33/304.ccls. and twin$3	USPAT	OR	ON	2005/06/01 17:51
S15	1	33/304.ccls. and twin$3	USPAT	OR	ON	2005/06/02 15:52
S16	201	33/304.ccls.	USPAT	OR	ON	2005/06/02 15:53
S17	33	33/304.ccls. and wellbore	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:16
S18	2	33/304.ccls. and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:18

S19	0	174/45.ccls. and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:18
S20	7	(174/45.ccls. or 33/304.ccls. or 324/345.ccls. or 166/250.13.ccls. or 702/10.ccls. or 166/255.ccls.) and twin$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:22
S21	6	((borehole) or (bore same hole)) same twin$4 and vector and magnetic	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:29
S22	61	horizon$4 same plane and vertical and magnetic same north and magnetic same azimuth and magnetic same east	US-PGPUB; USPAT	OR	ON	2005/06/02 16:31
S23	28	horizon$4 same plane and vertical and magnetic same north and magnetic same azimuth and magnetic same east and borehole	US-PGPUB; USPAT	OR	ON	2005/06/02 16:31
S24	2	wellbore and drill$3 and passive same rang$3 same technique$3 and borehole same survey$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/02 16:45
S25	36	("3725777" "5512830" "5657826" "3170137" "4302886" "4909336" "4987684" "5194859" "5220963" "5259466" "5351755" "5415238" "5419405" "5439064" "5842149" "5996711" "6003599" "6021377" "6065550" "6092610" "6145378" "6173773" "6192748" "6233524" "6267185" "6296066" "6315062" "6453239" "6470976" "200200052286" "20020005297" "20020116130" "20020133958" "5675488" "6321456" "6480119" "20020144417").pn.	US-PGPUB; USPAT	OR	ON	2005/06/02 16:58

| S26 | 50 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. | US-PGPUB; USPAT | OR | ON | 2005/06/03 10:44 |

Plus

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	50	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn.	US-PGPUB; USPAT	OR	ON	2005/06/03 15:11
L2	49	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole	US-PGPUB; USPAT	OR	ON	2005/06/03 15:10
L3	0	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and twinning	US-PGPUB; USPAT	OR	ON	2005/06/03 15:10

L4	1	33/304.ccls. and twin$4	USPAT	OR	ON	2005/06/03 15:11
L5	34	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drilling	US-PGPUB; USPAT	OR	ON	2005/06/03 15:12
L6	34	("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3	US-PGPUB; USPAT	OR	ON	2005/06/03 15:12

| L7 | 17 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3 and magnetic same vector | US-PGPUB; USPAT | OR | ON | 2005/06/03 15:12 |
| L8 | 9 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3 and magnetic same vector and target same angle | US-PGPUB; USPAT | OR | ON | 2005/06/03 15:13 |

| L9 | 8 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3 and magnetic same vector and target same angle and ((first or second) same measure$4) | US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2005/06/03 15:16 |
| L10 | 0 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3 and magnetic same vector and target same angle and ((first or second) same measure$4) and tft | US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2005/06/03 15:15 |

| L11 | 1 | ("5230387" "5064006" "4957172" "5675488" "4791373" "4833787" "4920655" "4433491" "5305212" "6405808" "6438495" "4072200" "6026913" "4468863" "4611405" "4472884" "4909336" "5646611" "4901804" "4987684" "5821414" "5892460" "5513710" "6188222" "5259466" "5806194" "5585790" "6026914" "5467832" "5448227" "5488989" "6164377" "6480119" "6882937" "6736222" "5929540" "5229939" "5390748" "4311912" "5667025" "4956921" "5193628" "4999920" "4852069" "5485089" RE36569 "4372398" "4329647" "5343152" "5955884").pn. and borehole same survey and drill$3 and magnetic same vector and target same angle and ((first or second) same measure$4) and tool same face same target | US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2005/06/03 15:15 |